





# Returning to the Moon: NASA's Artemis Missions

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Spaceflight Division Chief

NASA Ames Research Center

February 15, 2022



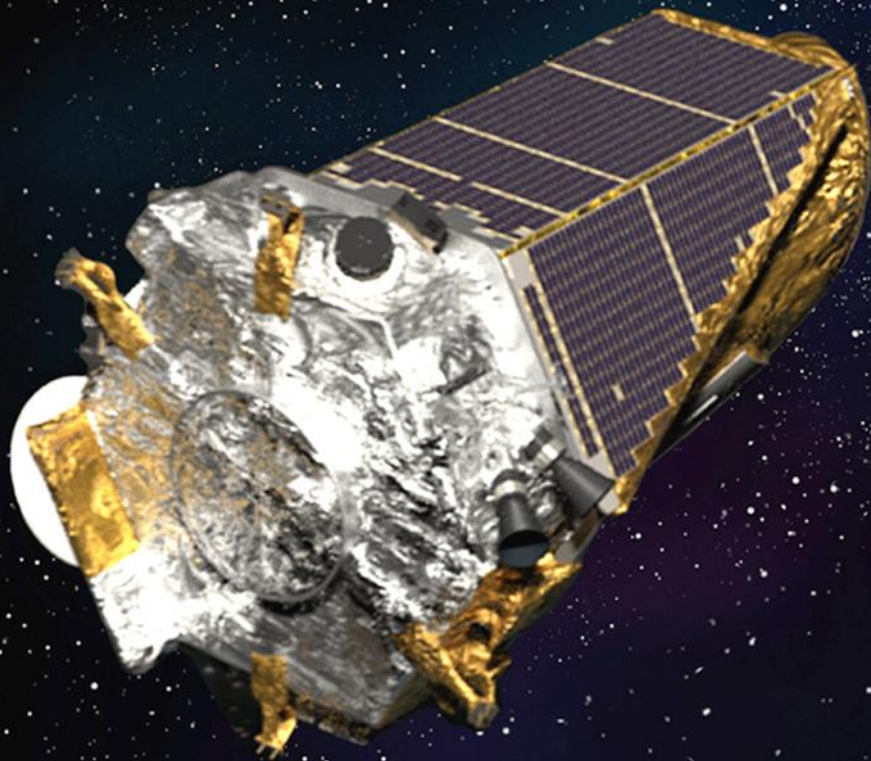
Almaden Country Day School  
Space Exploration Class





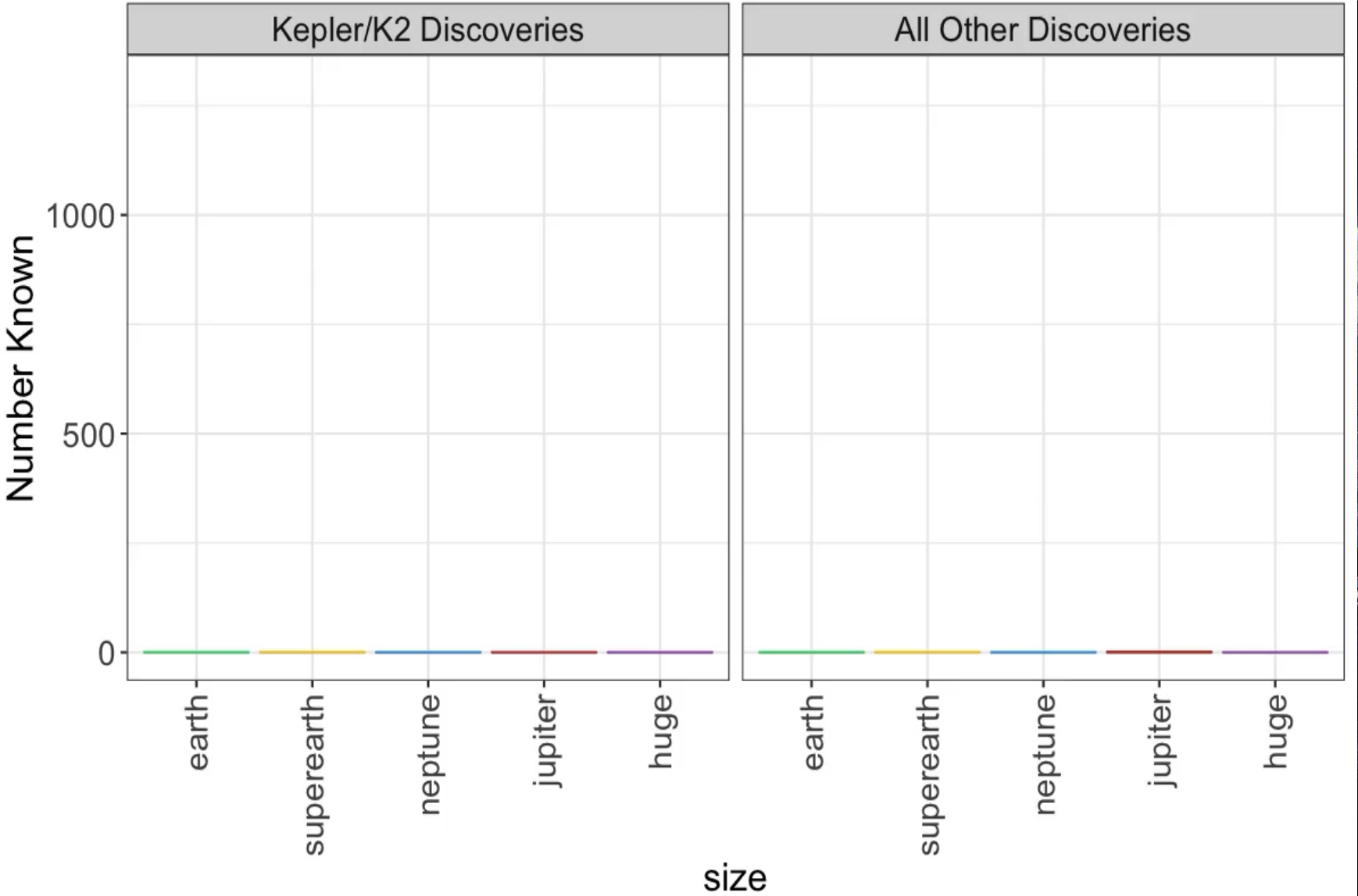


# Kepler





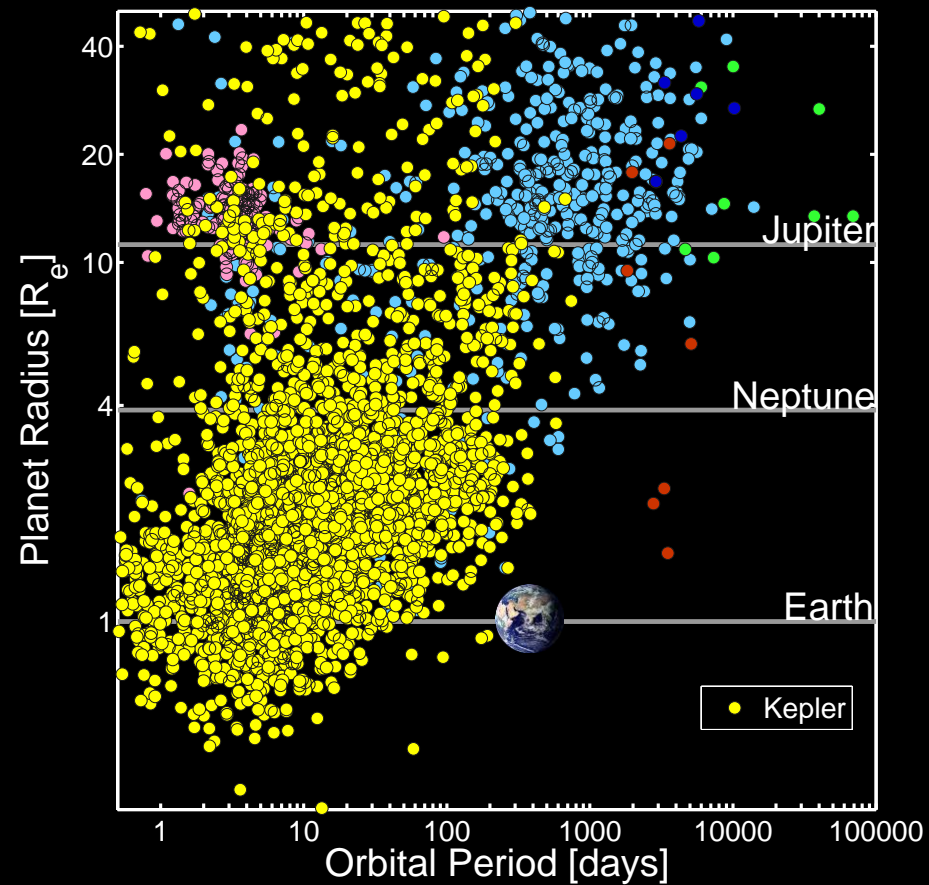
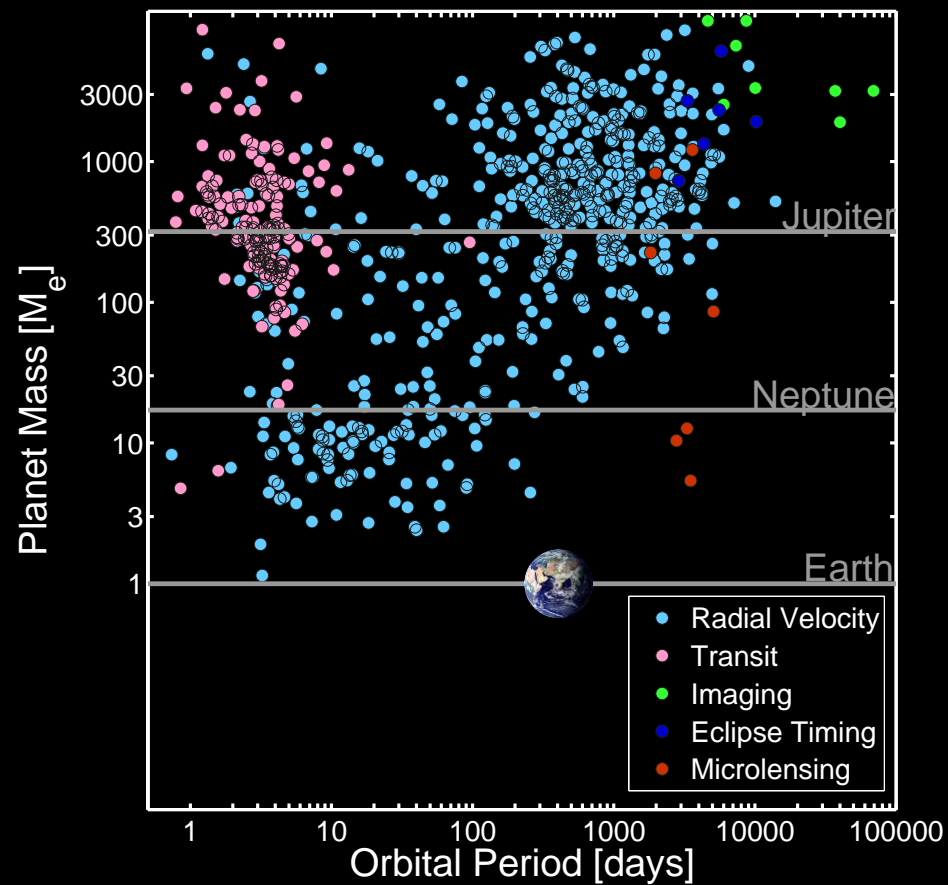
# Confirmed Planets as of 1989



Navigation and Administration



data from NEXSci





Earth  
DIAMETER  
7,926 miles

## WHERE IS THE PLANET?

1,400 light-years away, or 8.4 quadrillion miles, in the constellation Cygnus. It is circling Kepler-452, a G-class star similar to our sun.

452b  
DIAMETER  
12,700 MILES

## HOW BIG?

Kepler-452b is roughly 60% larger than Earth.

# USA TODAY WEEKEND

A GANNETT COMPANY

## EARTH TO 452b

New planet found outside our solar system could harbor life

Traci Watson  
Special for USA TODAY

Scientists have spotted a planet much the same size as our Earth orbiting a star that closely resembles our sun, making it the most likely known place outside our solar system to harbor life.

The newfound planet, Kepler-452b, "is the closest thing we have to another place that somebody else might call home," Jon Jenkins of NASA's Ames Research Center told reporters Thursday. The planet has been at just the right temperature to boast liquid water for some 6 billion years, "a considerable time and opportunity for life to arise somewhere on its surface or in its oceans," assuming the place has all the necessary ingredients for life, Jenkins said.

Researchers have found other planets outside the solar system that are nearly the same

probably rocky, as Earth is. But those planets circle dim, cool stars very different from our own sun, whereas 452b is hitched to a star very much like ours. If we could send plants to 452b, Jenkins said, they could comfortably photosynthesize.

The new planet is about 60% bigger in diameter than Earth,

**"We're getting closer and closer to a true Earth analog."**

Joshua Pepper, astronomer

the researchers said. It has a better-than-even chance of having a rocky surface, which would make a good platform for life to gain a foothold. Assuming it's rocky, it would have active volcanoes and perhaps a thick atmosphere.

This new Earth cousin was spotted by NASA's Kepler telescope, which watched for barely

of light coming from stars in the constellations Lyra and Cygnus. The planet, which is some 1,400 light-years from Earth, is described in a new article in *The Astronomical Journal*.

Other scientists who were not involved in the research called 452b an exciting example of a planet in the "Goldilocks" zone, where it's neither too hot nor too cold for liquid water to persist. "You could say this is the first viable 'Goldilocks' planet — with dozens more potentially," said MIT astronomer Sara Seager via email.

All the same, it's not clear that 452b is rocky. It could be made of ice, or it could have a thick hydrogen envelope that would choke off the possibility of life, said astronomer Joshua Pepper of Lehigh University.

"We're getting closer and closer to a true Earth analog," Pepper said. "But it's going to take a long time before we can confirm whether these planets

## 41,500 VA HEALTH POSITIONS UNFILLED

Lack of medical staff pushes vets to costlier care

Meghan Hoyer  
and Gregg Zoroya  
USA TODAY

The Veterans Health Administration has 41,500 job vacancies for doctors, nurses and other medical professionals across its sprawling health care system while it struggles to provide timely medical care for veterans, according to records analyzed by USA TODAY.

The failure to fully staff hospi-

### NEWSLINE

#### IN NEWS

**Chemo doesn't help end-stage cancer, study says**

Quality of life actually made worse for some.

**Angry Greeks say #BoycottGermany**

Germany took lead in demanding tough bailout terms.

#### IN MONEY

**Whew! Earnings season not so bad**

72 of 104 in S&P 500 that have reported earnings exceeded expectations.

#### IN SPORTS





### WHAT HAS *KEPLER* FOUND?

Most stars have planets.

Planetary systems have been forming from  
the beginning of our galaxy.

Earth-size planets are common.

Planets unlike any in our Solar System are common

Planets of all sizes are found in the habitable zone.

Other planetary systems are quite unlike ours.

→ Implications: Fermi paradox

### WHAT'S NEXT?





# The Artemis Missions

Artemis is the twin sister of Apollo and goddess of the Moon in Greek mythology. Now, she personifies our path to the Moon as the name of NASA's program to return astronauts to the lunar surface.

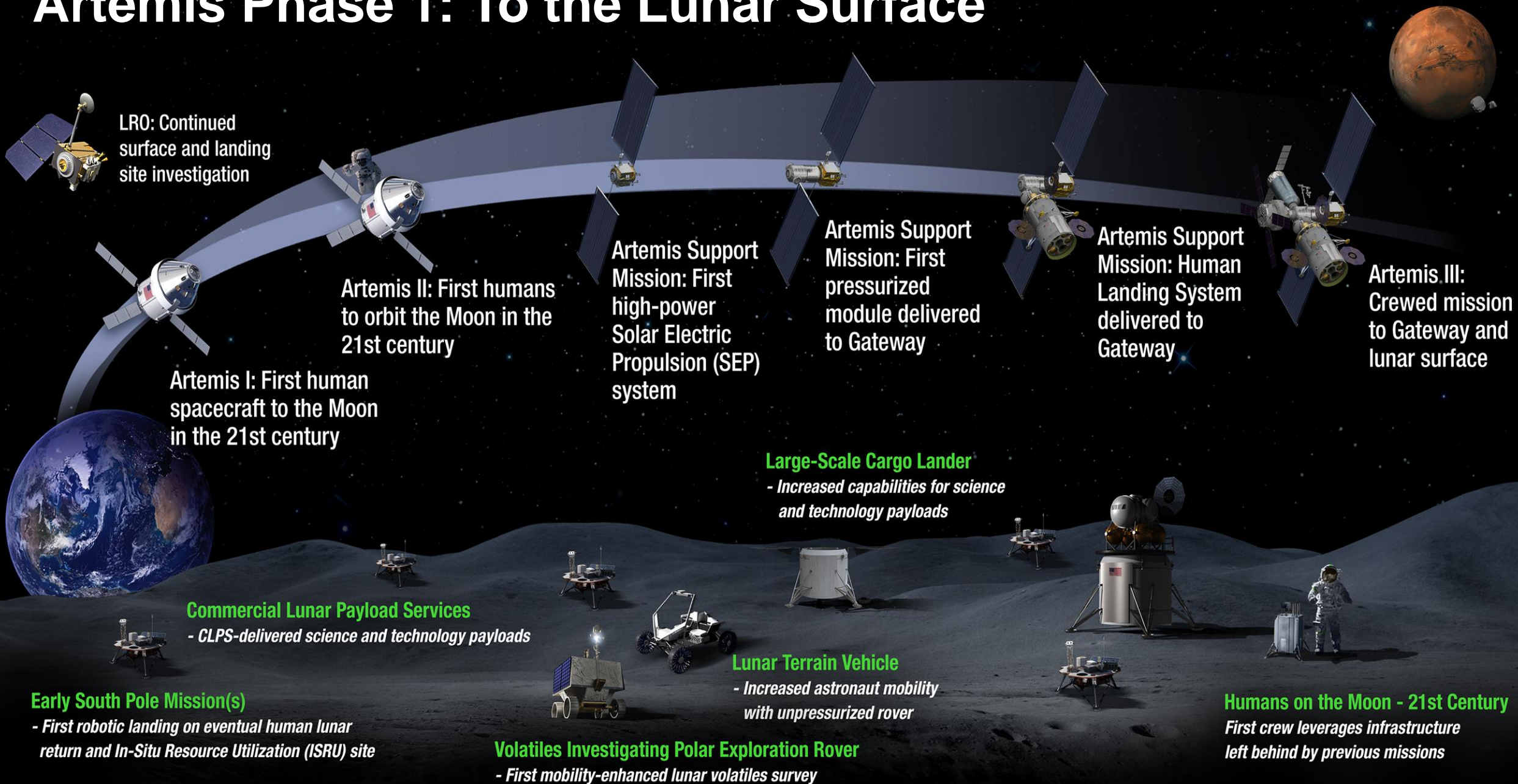
When they land, Artemis astronauts will step foot where no human has ever been before: the Moon's South Pole.

With the horizon goal of sending humans to Mars, Artemis begins the next era of exploration.





# Artemis Phase 1: To the Lunar Surface



**LUNAR SOUTH POLE TARGET SITE**



# VALUABLE LUNAR SCIENCE



Study of Planetary  
Processes



Understanding  
Volatile Cycles



Impact History of  
Earth-Moon System



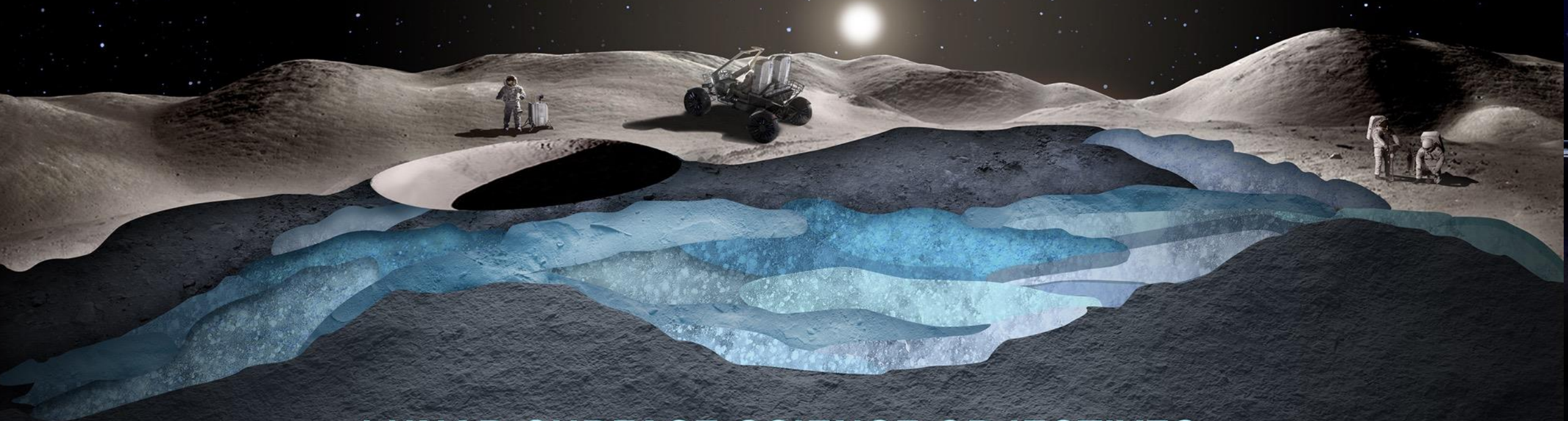
Record of the  
Ancient Sun



Fundamental  
Lunar Science



Platform to Study  
the Universe



## LUNAR SURFACE SCIENCE OBJECTIVES





# Mission Needs Drive Design

## LOW EARTH RETURN

**3 HOURS**

**3,000°F**

**17,500 MPH**

**250 MILES**



## LUNAR RETURN

**3 DAYS**

**5,200°F**

**24,700 MPH**

**240,000 MILES**



## MARS RETURN

**9 MONTHS**

**6,200°F**

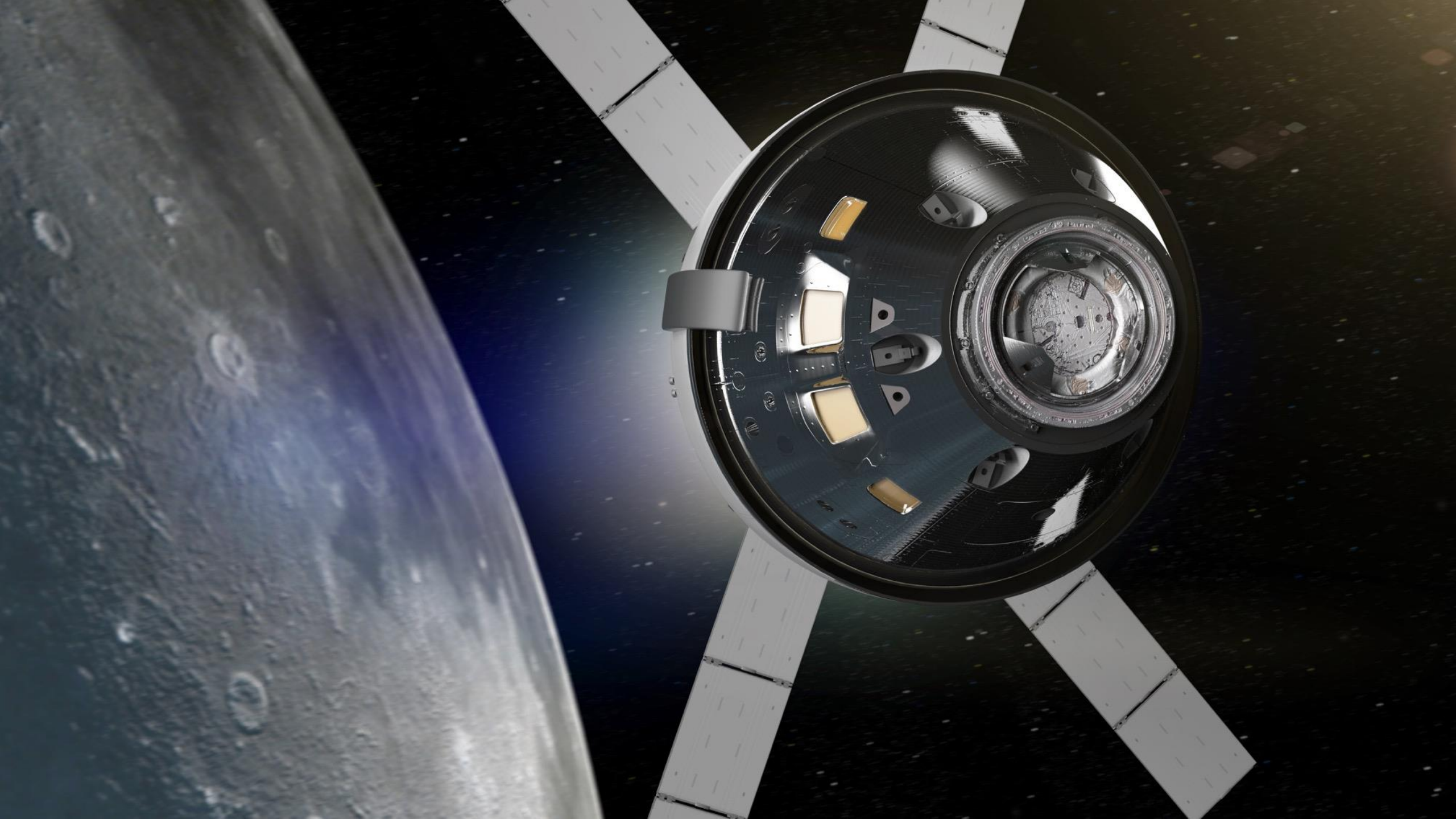
**26,800 MPH**

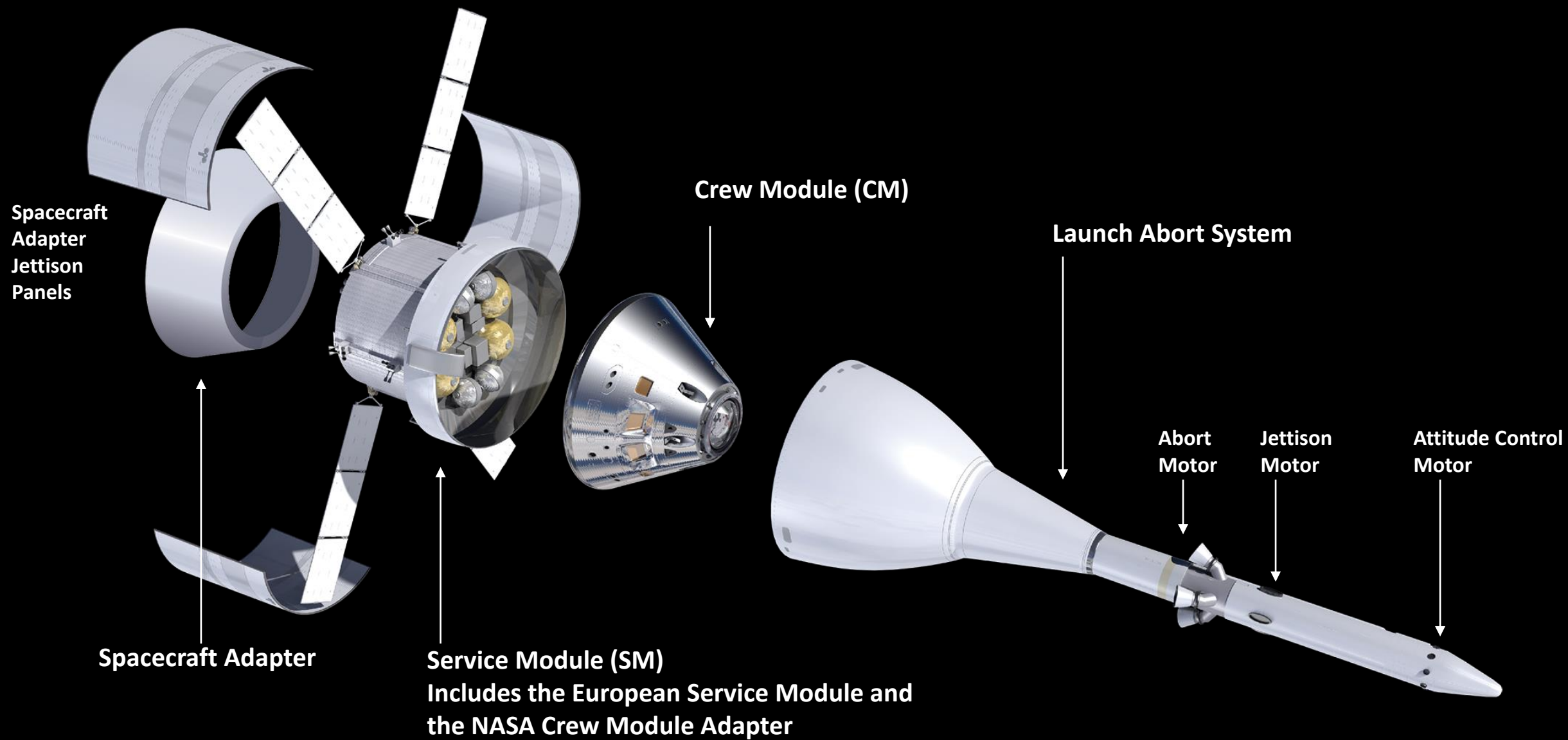
**39,000,000 MILES**



*\*Numbers are averages*











NAVY

10 WHEEL LOAD 125K 95% WHEEL LOAD  
FORNITE

HE 001-083





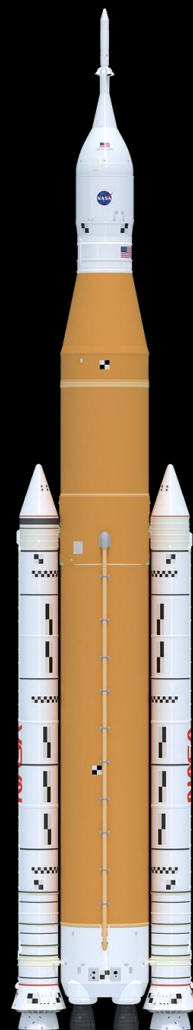




STATUE OF LIBERTY  
305 ft.



SPACE SHUTTLE  
184 ft.



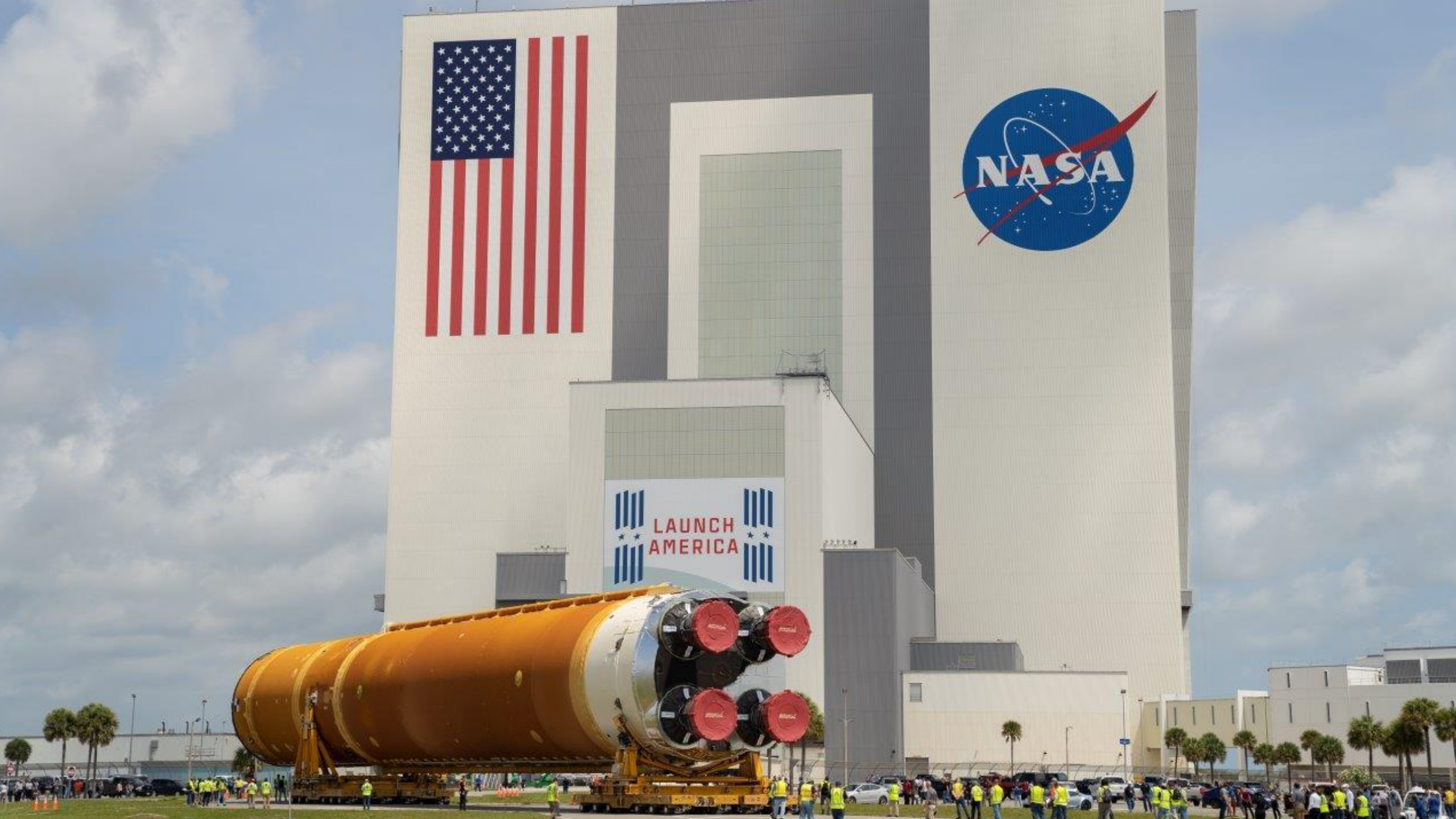
SLS / ORION Block I  
322 ft.



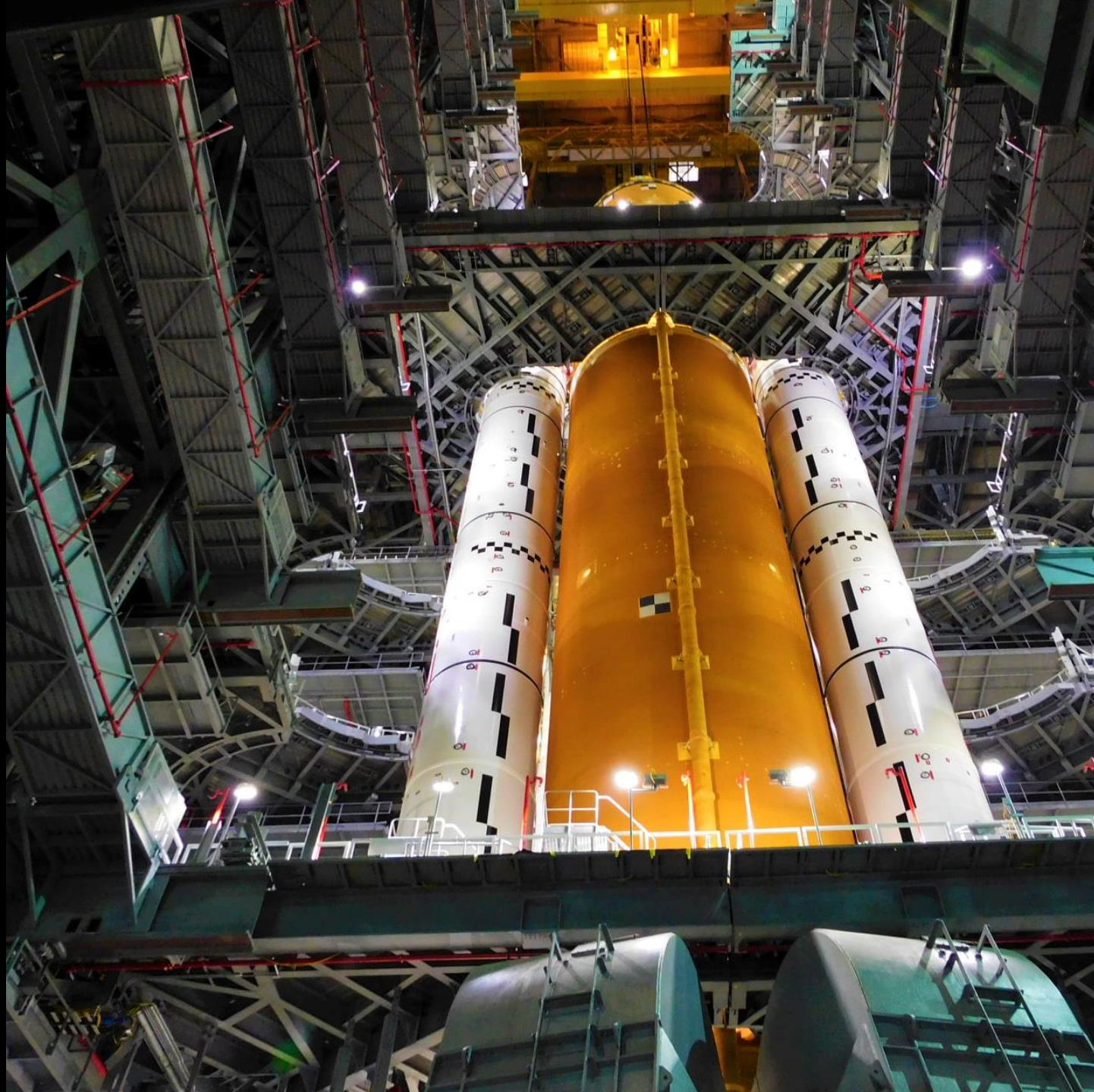
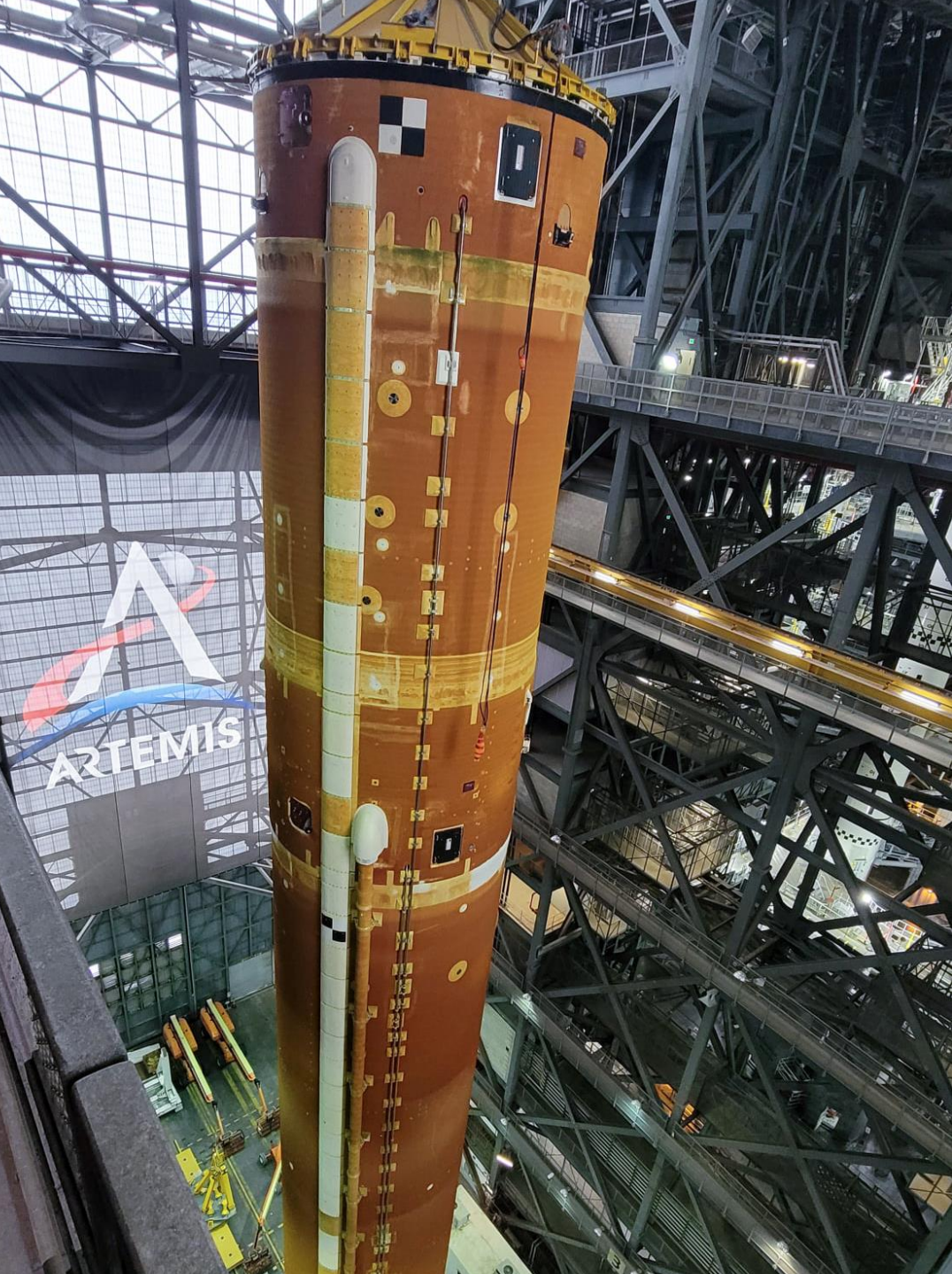
SLS / ORION Block II  
364 ft.



SATURN 5  
363 ft.



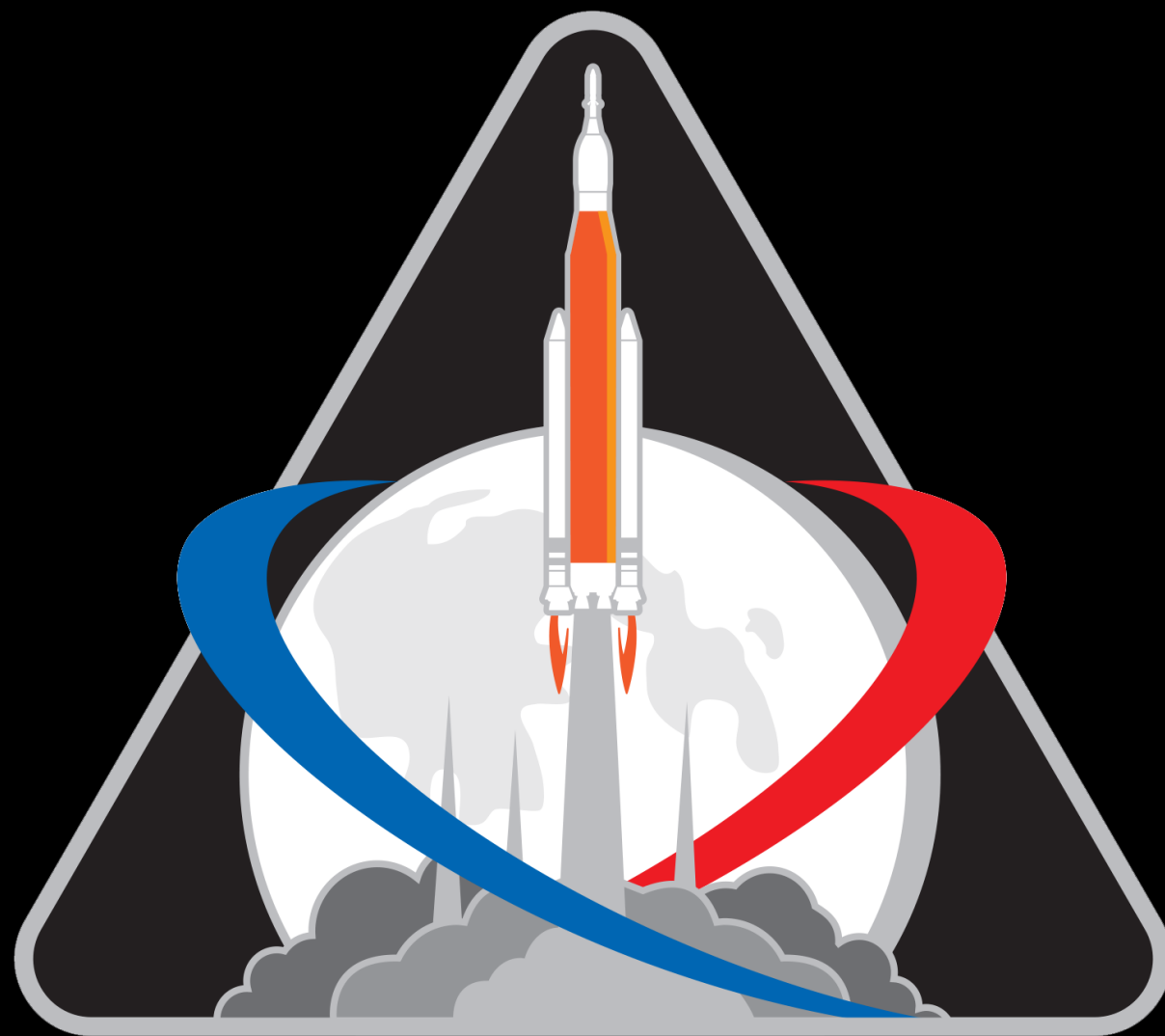












ARTEMIS I





# ARTEMIS II







Mode Norm

RHC Pur	On	1	2	3
Pitch	0	0	0	
Yaw	0	0	0	
Roll	0	0	0	

Switch 1 Auto  
Switch 2  
Switch 3  
Switch 4

THC Pur	On	1	2	3
X	0	0	0	
Y	0	0	0	
Z	0	0	0	

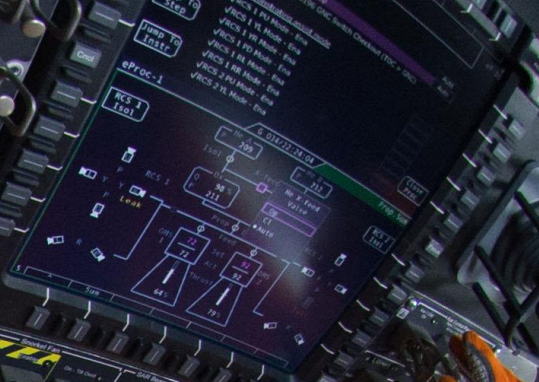
Switch

Mode Norm

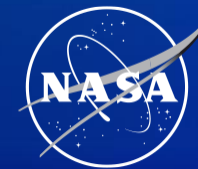
RHC Pur	On	1	2	3
Pitch	0	0	0	
Yaw	0	0	0	
Roll	0	0	0	

Switch 1 Auto  
Switch 2  
Switch 3  
Switch 4

THC Pur	On	1	2	3
X	0	0	0	
Y	0	0	0	
Z	0	0	0	







Joseph  
**ACABA**

Kayla  
**BARRON**

Raja  
**CHARI**

Matthew  
**DOMINICK**

Victor  
**GLOVER**

Warren  
**HOBURG**

Jonny  
**KIM**

Christina H.  
**KOCH**

Kjell  
**LINDGREN**



Nicole A.  
**MANN**

Anne  
**McCLAIN**

Jessica  
**MEIR**

Jasmin  
**MOGHBELI**

Kate  
**RUBINS**

Frank  
**RUBIO**

Scott  
**TINGLE**

Jessica  
**WATKINS**

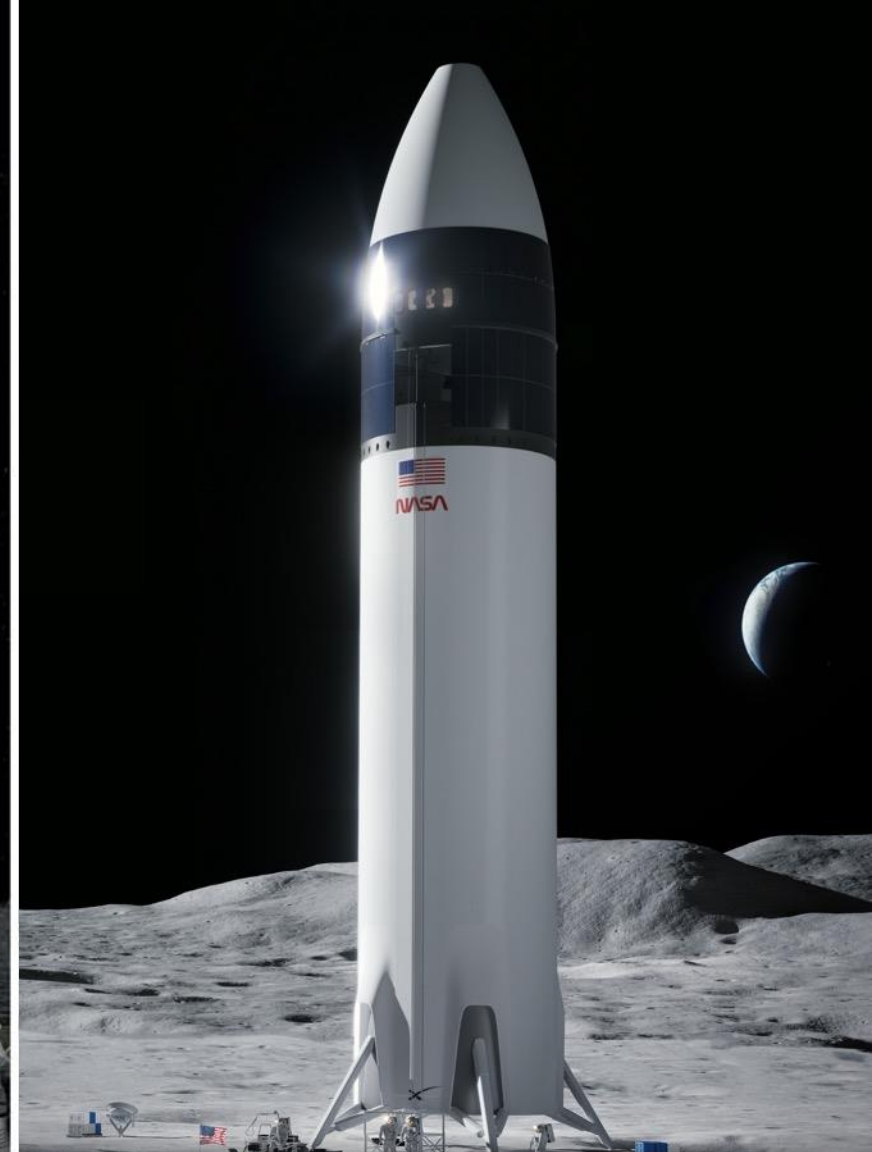
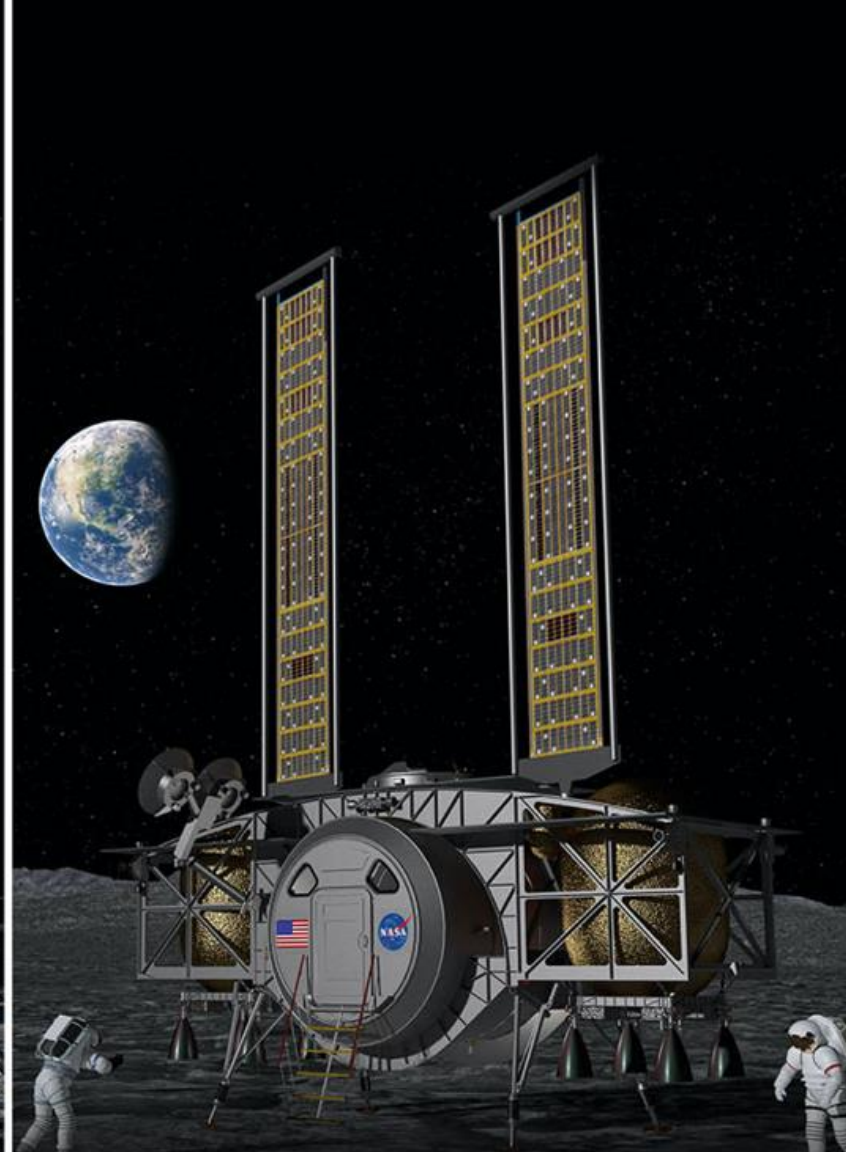
Stephanie D.  
**WILSON**



# ARTEMIS III







LOCKHEED MARTIN

BLUE ORIGIN

NORTHROP GRUMMAN

DRAPER

**Dynetics**  
A Leidos Company

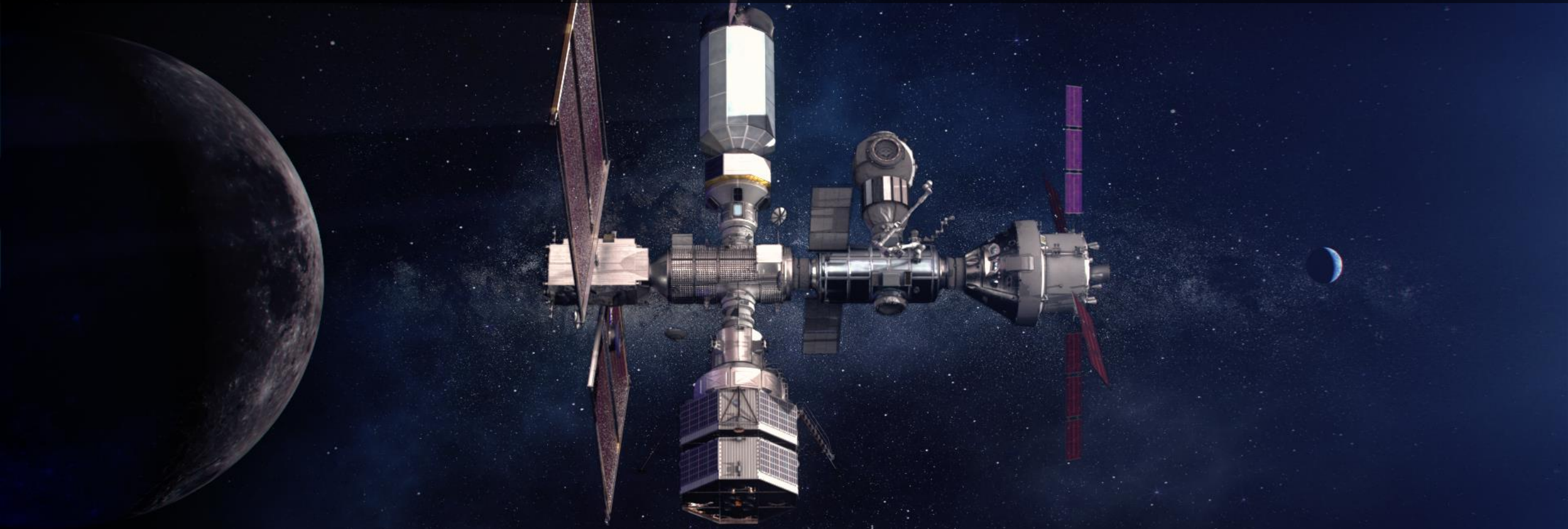
**SPACEX**





# Gateway International Partners

*Building on ISS partnerships to expand deep space capabilities*



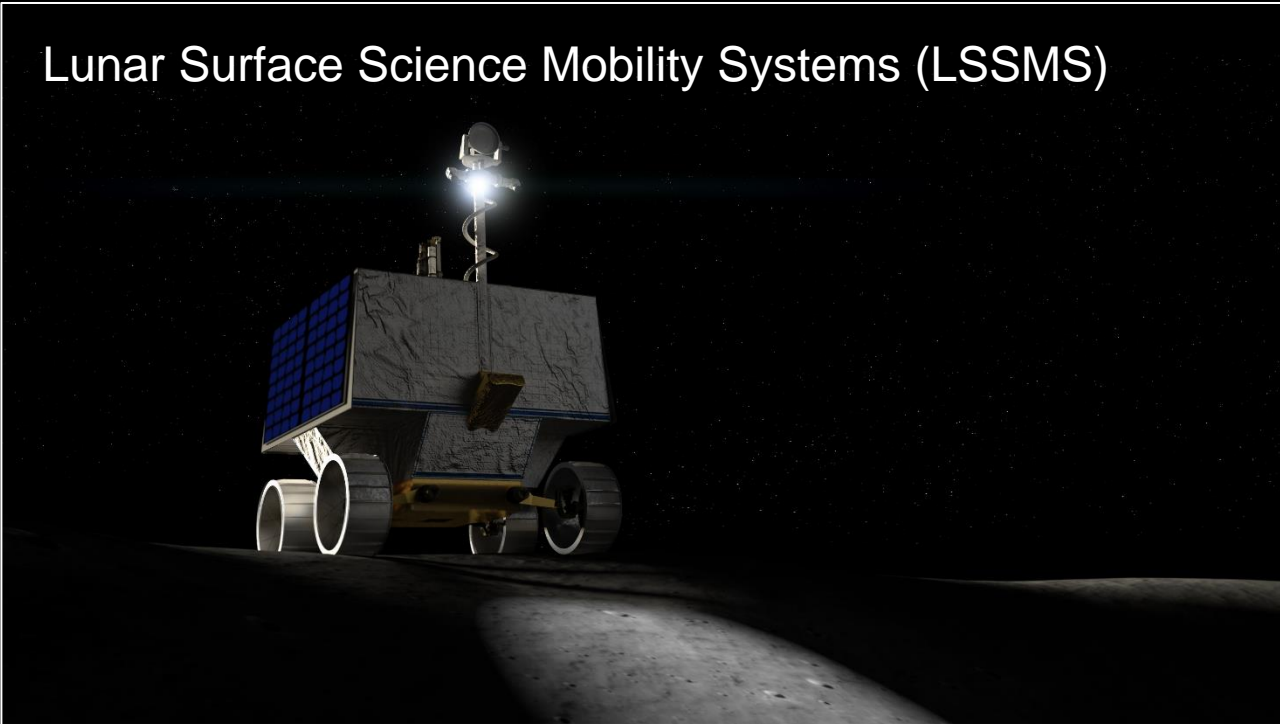
# Ideas for Lunar Human and Robotic Rovers

Lunar Terrain Vehicle (LTV)



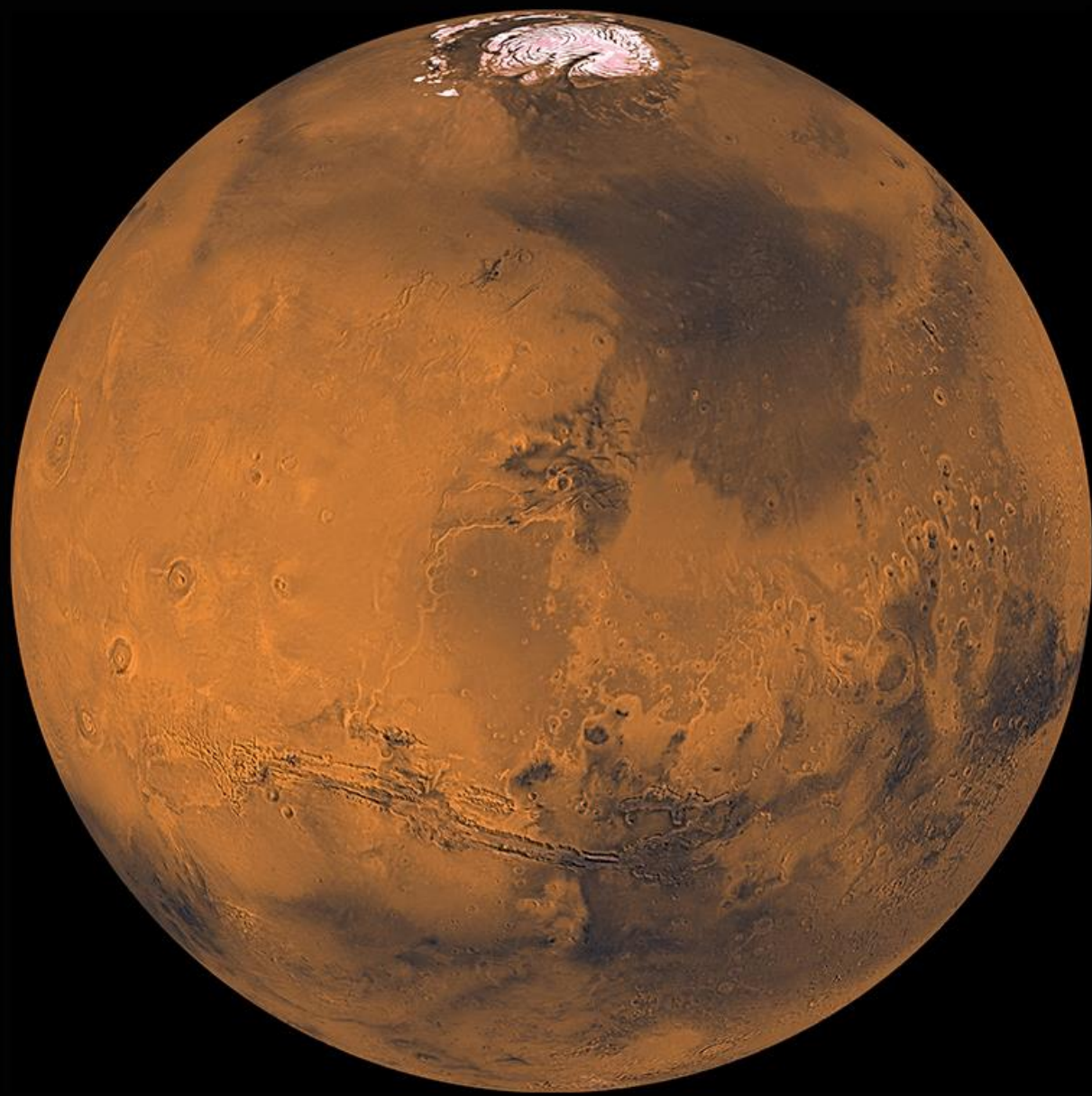
Human-rated, to move two suited astronauts across the lunar surface

Lunar Surface Science Mobility Systems (LSSMS)



Robotic vehicles to transport instruments across the lunar surface



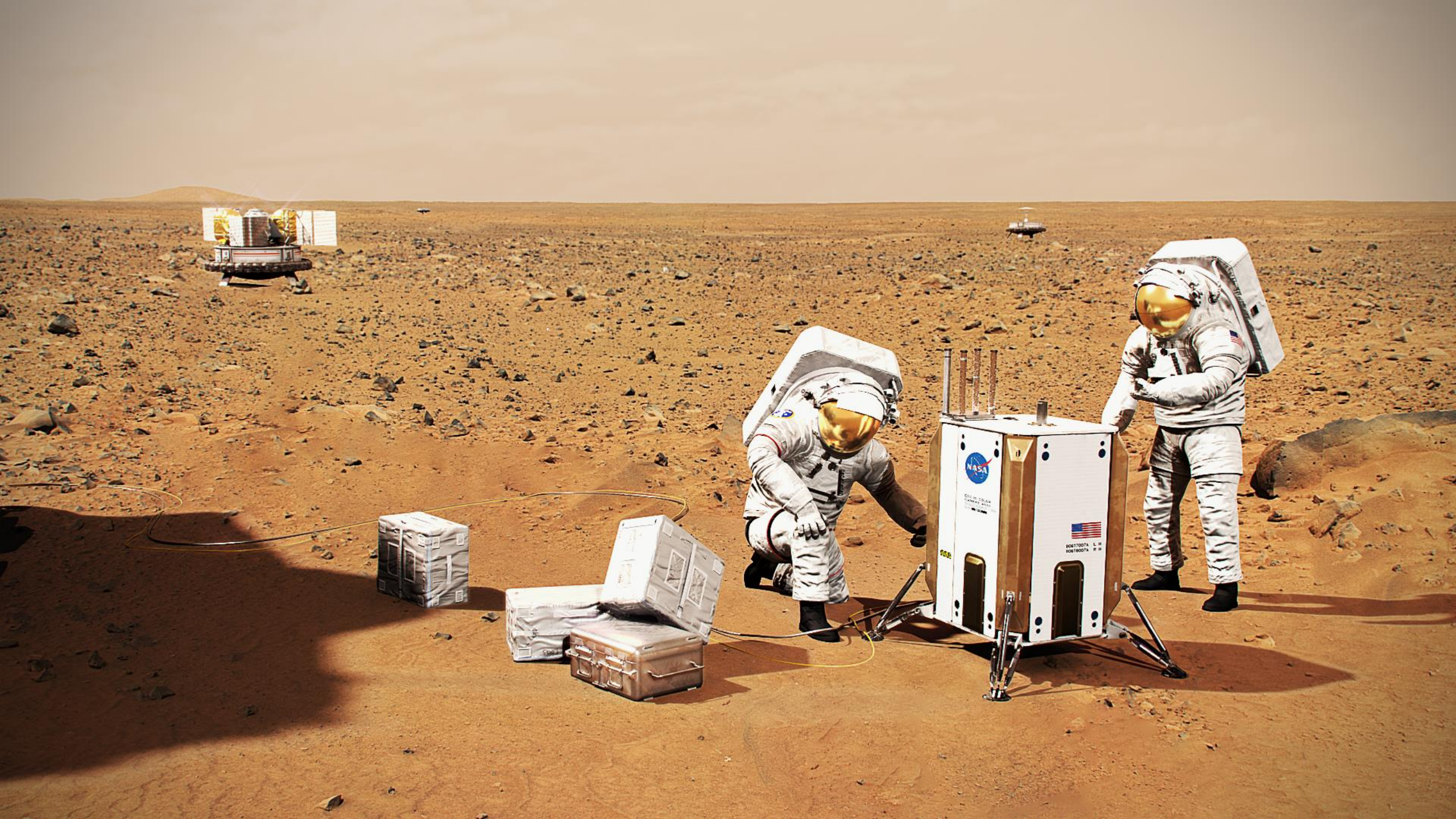


# Bots Before Boots

*Robots living and working on Mars today pave the way for smarter, safer human exploration of the lunar south pole*









# Taking the Next Giant Leap

*Humans on Mars*



Earth





**Welding  
Technician**



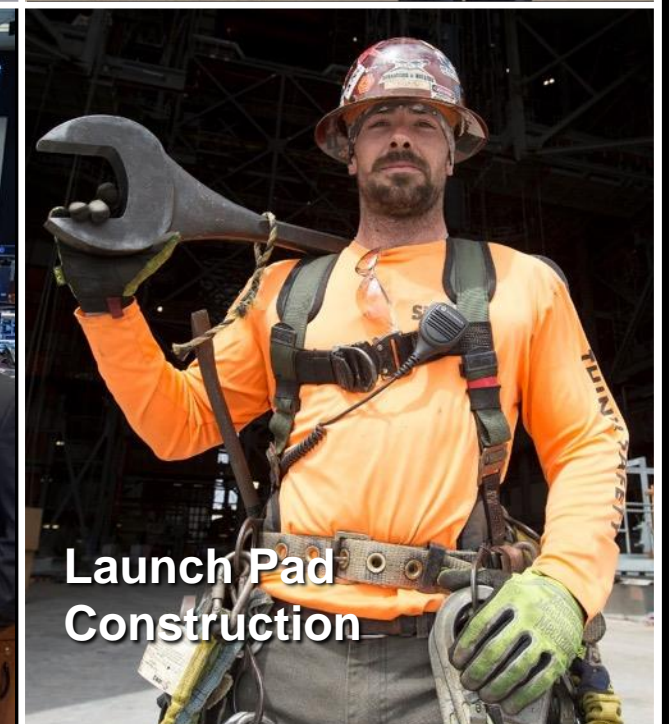
**Avionics  
Technician**



**Food  
Scientist**



**Flight Controller**



**Launch Pad  
Construction**

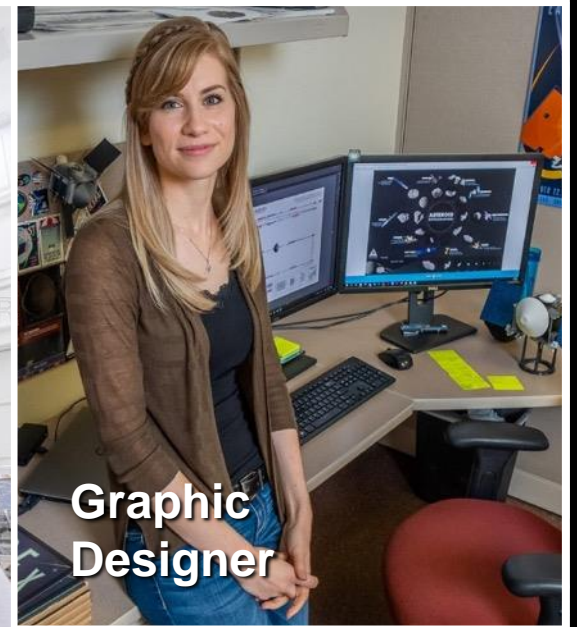




**Social Media**



**Robotics Designer**



**Graphic Designer**



**Spacesuit Designer**



**Geologist**



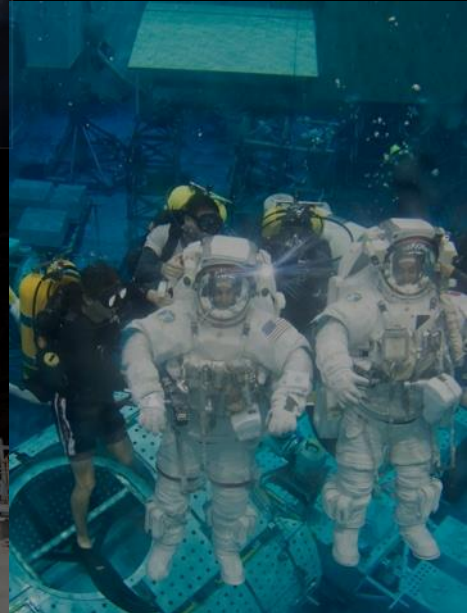
**Astronaut Trainer**





# EXPLORATION IS A TEAM SPORT

We have the right plans and the right  
teams in place to carry our plans  
forward.  
Now we GO.









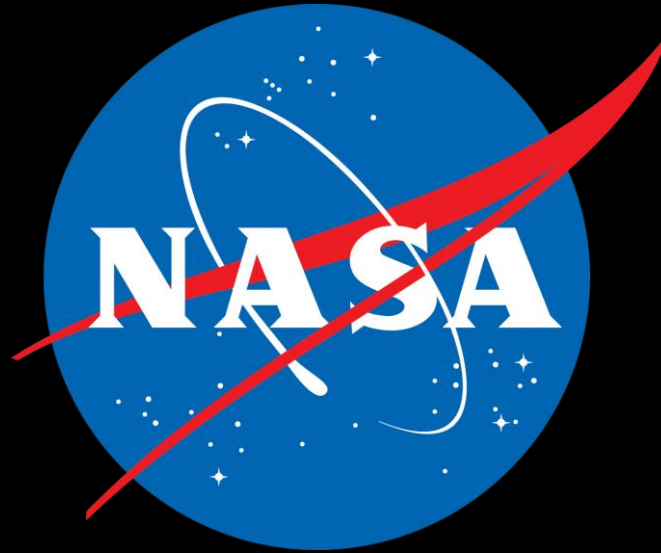






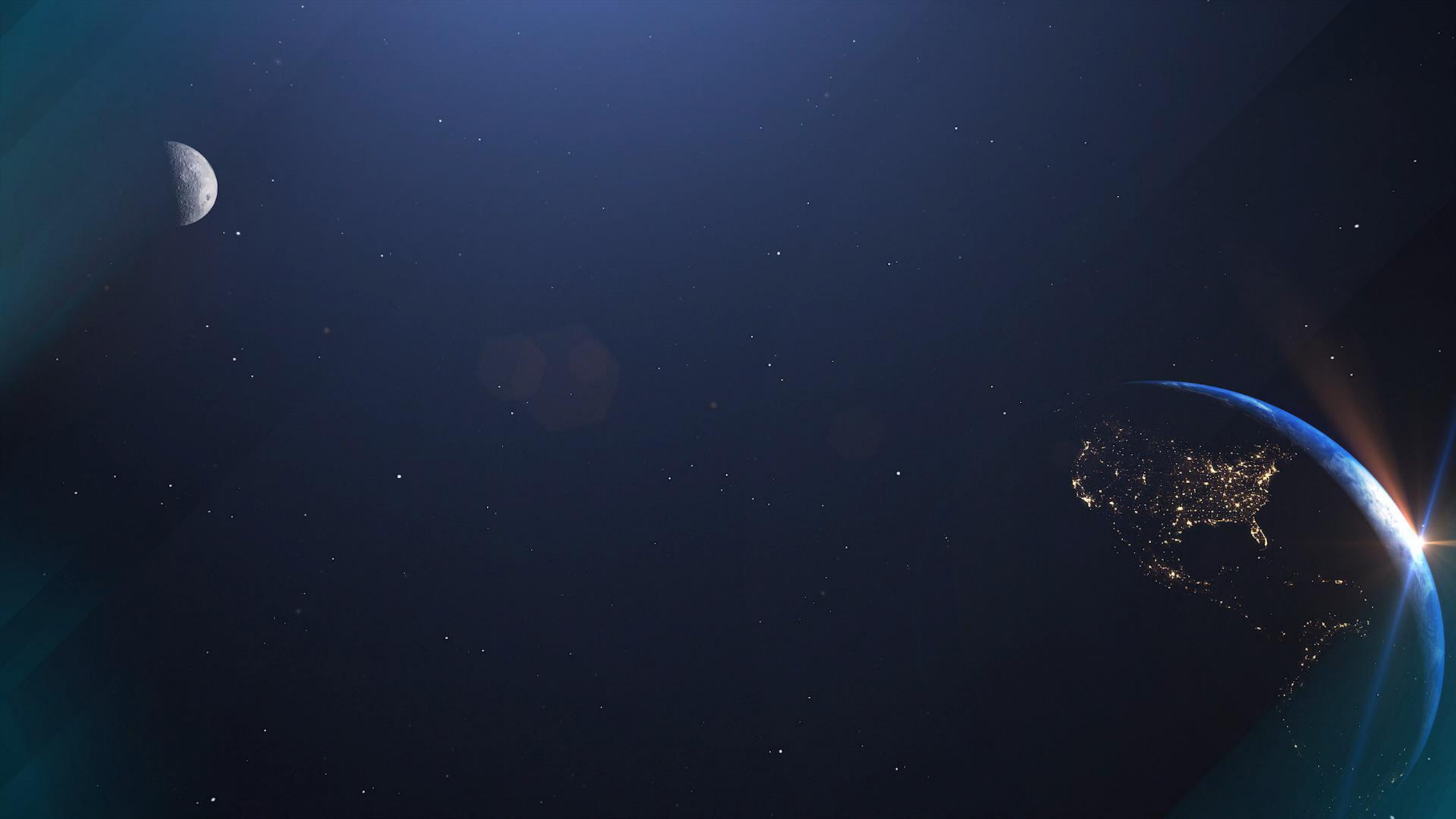
**QUESTIONS?**





**Back Up Slides**













# ARTEMIS

Expanding Partnerships  
to the Moon

The recently released Artemis Accords demonstrate the commitment of both NASA and international partners to peaceful exploration, transparency, interoperability, and the sharing of scientific data as we move to a new frontier – sustainable deep space exploration.



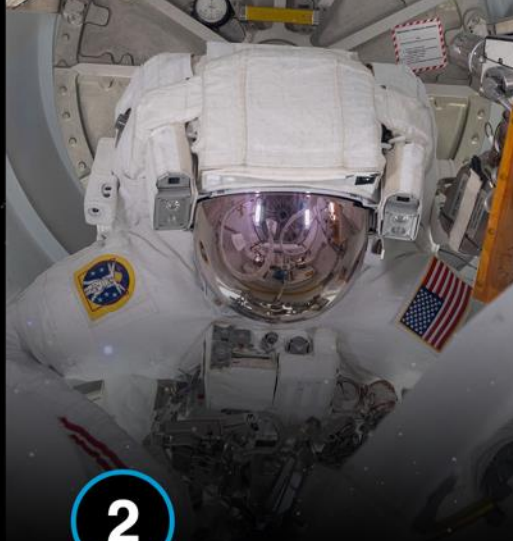


# Hazards of Human Spaceflight

1

## Space Radiation

Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.



2

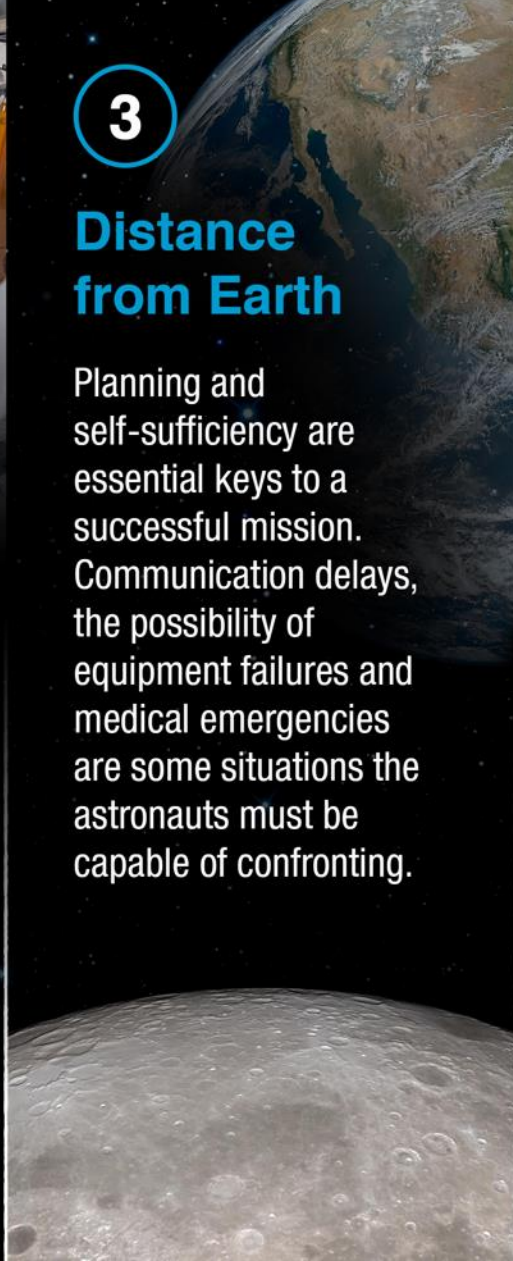
## Isolation and Confinement

Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.

3

## Distance from Earth

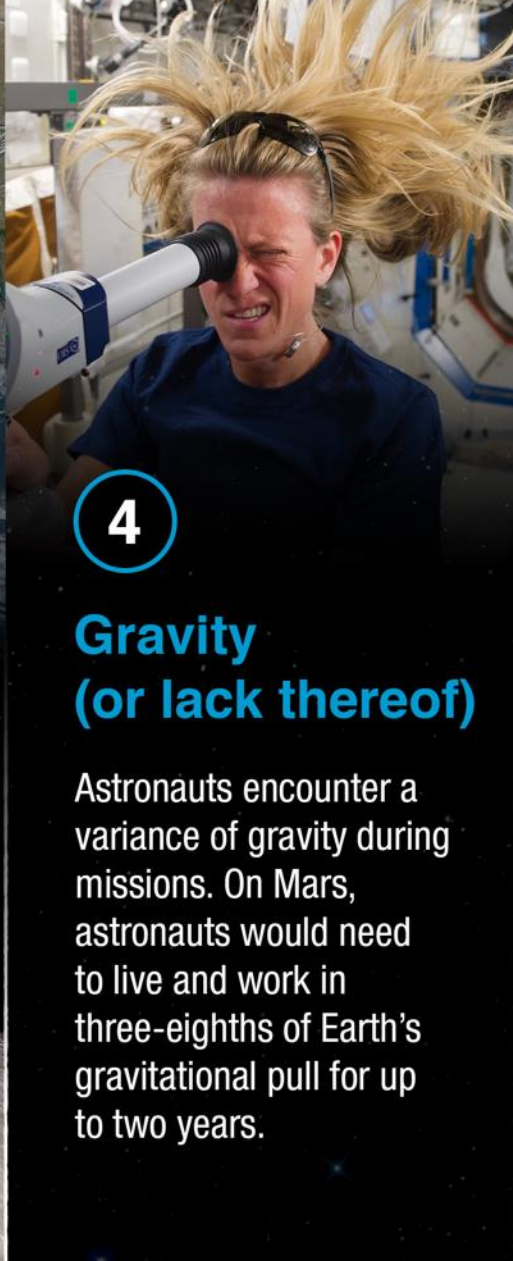
Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.



4

## Gravity (or lack thereof)

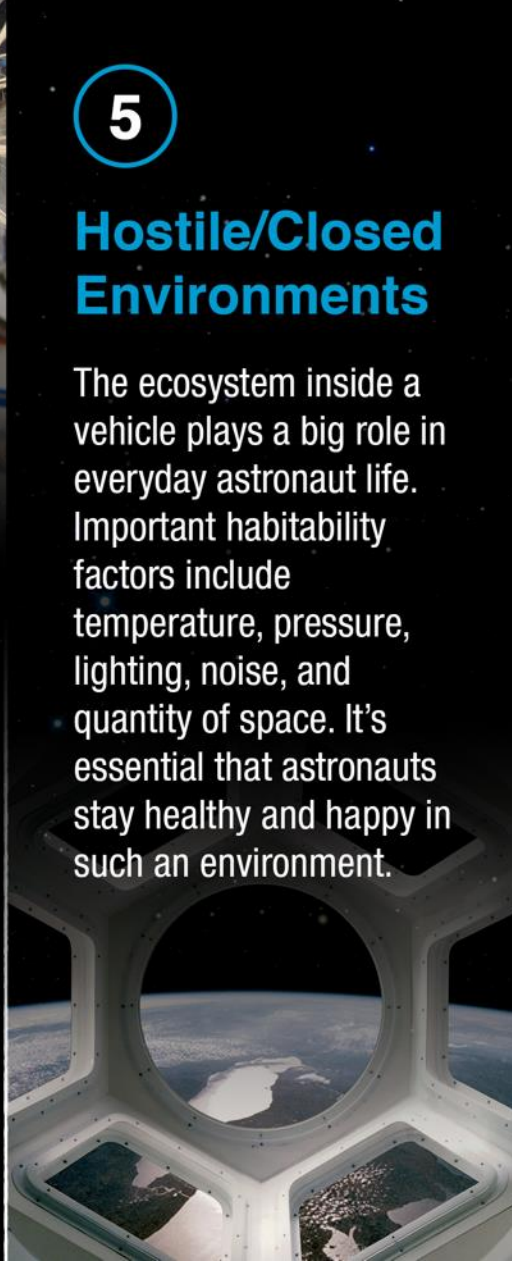
Astronauts encounter a variance of gravity during missions. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years.



5

## Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.



# Unpressurized Rover

*Lunar Terrain Vehicle*





# Pressurized Rover





# Commercial Lunar Payload Services

*14 CLPS providers are currently on contract and eligible to bid on payload deliveries to the Moon*





# Orion Crew Survival System



Protects astronauts during launch, reentry and emergency situations during Artemis missions

- Custom-fit for each crew member
- Lighter, more comfortable helmet with noise reduction and easier connection to the communications system





# MOONWALKING IN THE MODERNIZED SPACE SUITS

NASA is working with industry to design and build the modernized spacesuits for Artemis missions, called *Exploration Extravehicular Mobility Unit*, or xEMU

Spacesuit improvements include advanced safety additions, more flexibility, better communications, and custom fitting.





# MARS

## SURFACE MISSIONS



### **2011 CURIOSITY**

Measuring radiation levels at the surface and the composition of Martian rocks and atmosphere



### **2018 INSIGHT**

Understanding tectonic activity and meteorite impact rate



### **2020 PERSEVERANCE**

Demonstrate production of oxygen from Martian atmosphere; monitor weather at the surface; sample collection, demonstrating improved landing accuracy and safety using Terrain Relative Navigation (TRN)



### **2022 EXOMARS ROVER**

Meter deep drilling to the subsurface and studying chemical building blocks of life



### **2026 MARS SAMPLE RETURN**

First round-trip to Mars, demonstrating launching from the Martian surface and in-orbit rendezvous

## ORBITER MISSIONS



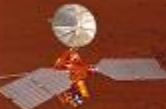
### **2001 MARS ODYSSEY**

Identifying regions with buried water ice



### **2003 MARS EXPRESS**

Detecting liquid water under the south pole



### **2005 MRO**

Mapping and understanding potential landing sites and local resources



### **2013 MAVEN**

Investigating the history of Mars' climate; studying solar wind and ionosphere



### **2016 EXOMARS ORBITER**

Precision navigation on Mars



### **2024 MMX**

Sample collection on Martian Moons



### **2026 ICE MAPPER**

First near global map of water-ice resources in the near-subsurface



# Humans on Mars

*Pushing the Boundaries  
of Current Possibilities*



## Go

*Rapid, safe, & efficient  
space transportation*

## Land

*Expanded access to  
diverse surface  
destinations*

## Live

*Sustainable living  
and working farther  
from Earth*

## Explore

*Transformative missions  
and discoveries*